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MEMO

TO: Russell Larson
FROM: Allan Klumpp
DATE: January 12, 1971
SUBJECT: Anomalies in Apollo 14 Descent

Per Webster, An anomaly is a "deviation from the common rule; irregularity". There is no suggestion either that the anomaly is a flaw or that it is caused by a fault. An anomaly _may_ be a deficiency or produced by a deficiency, or it _may_ be merely a deviation from the common rule or norm which is acceptable and explicable by a less common, more obscure rule.

About sixteen such anomalies in Apollo 14 descent simulations are being examined and analyzed to determine the causes and the corrections required, if any. Most anomalies have been traced to sources which cannot affect the mission and are not discussed at this time. The remaining anomalies have been traced to the Luminary program or the erasable load. Each is listed along with the probable cause. The behavior in each case has been carefully examined and I am confident, although not yet certain in every case, that the cause has been determined. The continuing analysis is expected to establish within the next few days that the causes have been correctly identified, and a subsequent memo will be written at that time. It is gratifying that only the first three anomalies are related to any program characteristic would could be construed as a deficiency, and these were known and accepted characteristics at the time the program was designed.

1. Auto P66 removes the bulk of the forward velocity very quickly, but a residual error of about 0.7 fps decays with a time constant of about 10 seconds.

Cause: The pitch forward at the start of P66 causes the thrust direction filter of FINDCDUW to acquire a small error which decays with a time constant of about 10 seconds and produces a thrust pointing error during this interval.

Cure: If warranted, the thrust direction filter could redesigned to remember the past attitude or thrust pointing direction so as to eliminate the bulk of the filter error due to attitude rate.

2. About ± 2 fps variation in the rate of descent of P66 can occur even when P66 is entered automatically.

Cause: I am confident although not yet certain that the entire variation can be attributed to variation in the time-to-go of the last pass of P64, deviations of the terrain from the terrain model, noise in the radar, and other normal trajectory dispersions. Rate of descent variations were known and accepted at the time the auto-P66 program was designed.

Cure: Variations could easily be avoided by initializing the command descent rate at 3 fps if P66 was entered automatically, and initializing the command at the current descent rate if P66 was entered by ROD switch manipulation. The disadvantage of initializing at 3 fps in the automatic case is that possible substantial descent rate variations at P64 terminus would be involuntarily corrected immediately starting P66 with the engine going to maximum or minimum throttle. With an astronaut who normally has his hand on the ROD switch, we should let him decide how to correct descent rate dispersions rather than forcing upon him an immediate correction. Consequently I conclude the system is correctly designed and recommend against any such change. Also, the dispersions in P66 descent are nearly symmetrical about the nominal 3 fps. Therefore we conclude the P64 target erasables are correct.

3. Yaw error (defined as CDUY-CDUYD) of 1 degree or more persists for tens of seconds during P64 and P66.

Cause: With the DAP deadband of 0.3° and a phase plane logic containing a "flat" of 0.8°, the DAP does nothing to correct an attitude error of up to 1.1° providing it computes that the yaw rate error, however slight, is such as to diminish the yaw error. There are several ways, too elaborate to describe here, in which the yaw error can be produced. The resolution of FINDCDUW's rate commands is much finer than the resolution of the angle commands, which in many cases causes the DAP to erroneously compute that the yaw rate error is such as to diminish the yaw error; consequently the DAP does nothing and the error persists.

Cure: The flat was designed to facilitate transfer of U and V axes control to the trim gimbal. The trim gimbal does nothing for yaw, but the flat was retained in the yaw channel to preserve similarity with the other channels, the additional 0.8° yaw error not seeming objectionable. With azimuth-redesignation granularity to be 1°, the 1.1° yaw error may be objectionable, and perhaps the flat should be eliminated in yaw.

4. The yaw angle diverges gradually from zero during most of P64 to about 2°, and diverges rapidly a few seconds prior to P64 terminus to about 4°.

Cause: Cross-range dispersions in the initial velocity and Y axis velocity error produced by accelerometer bias is detected by the radar and produces a non-planar approach trajectory. Lowell Hull of Delco has pointed out that there is also an apparent Y axis velocity error due to truncation of the landing site update. However, this effect is comparatively small and we have not established numerically that it can be responsible for the apparent yaw-left bias. The cause of the sudden increase in the yaw rate a few seconds prior to the end of P64 has been traced to the algorithm which generates the window pointing command. The increase occurs as the LPD angle passes 65° and the algorithm switches from commanding the line-of-sight vector to commanding the Z axis of the guidance coordinate frame. The two command vectors would produce the same yaw angle except that the spacecraft is rolled about the Z axis by about $+0.8^{\circ}$ because the center of mass is not on the X axis. The roll suppresses the yaw until the window pointing command is switched, at which time the spacecraft yaws into alignment with the guidance coordinate frame.

Cure: This is a normal characteristic of the descent guidance. Unless someone can assert that such small yaw deviations are objectionable, nothing should be done.

5. One bit-by-bit simulation hit the top of a hill about 1.5 km short of the landing site while moving 47 m/s (105 mph).

Cause: An initial down range error of 3000 m produced a substantial mismatch between the terrain and the modeled terrain. In addition, a series of restarts during the pitch-forward maneuver at the start of P64 caused the maneuver to be delayed about 8 seconds (the autopilot stops attitude

rates and sets to zero attitude rate commands (ZATTEROR) during a restart). The delay in the maneuver caused the altitude to drop 70 meters below what would have occurred without the restarts, precisely the amount the trajectory would have otherwise cleared the hill.

Cure: With noun 69, the down range dispersion will be much smaller, and with landing site redesignation to the nominal site, the terrain model will be matched to the terrain.

6. Simulations are landing about two minutes earlier than TLAND.

Cause: The operational trajectory has recently been slightly redesigned, and the corrected initialization has not yet been put in the simulations.

Cure: We will shortly reinitialize to the new O.T.

7. The time under throttle control during the braking phase was about 30 seconds longer than expected.

Cause: One issue of the "Final H-3 Prelaunch Erasable Load Luminary 178" quoted RIGNZ as -1.484979987 + 006 ft. The correct value is -1.464979987 + 006 ft. Consequently the engine was ignited about 4 seconds early.

Cure: Automate the process of generating these erasables to eliminate human error. Every landing mission except possibly 13 has had at least one human error in the erasable load.